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Pedestrian Detection for Anti-Tampering Vehicle Protection

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ABSTRACT

Vehicle survivability in the form of anti-tampering tools is an important part of the FCS community of vehicles. Autonomous or semi-autonomous vehicles traversing through unknown terrain require the ability to detect, predict, and avoid potential aggression from hostile forces. Expanding upon pedestrian detection techniques will provide a viable solution in the near term.

With the current vision based pedestrian detection algorithms, an anti-tampering suite can be developed. First, the system must determine people in the scene. Once this is accomplished, the people can be checked for weapons and their movements can be tracked. Finally deciphering the tracked movements can help distinguish between friendly and unfriendly actions by people.

This paper will discuss the need for an anti-tampering suite and how pedestrian detection techniques can be used to address this need.

1. Introduction

The term anti-tamper when related to security systems means either a security device that destroys crucial data just before the information falls into enemy hands or a system that has the ability to detect when possible tampering of a system might take place. These capabilities needed throughout the army and the other forces. This paper will only talk about the latter; more specifically, detection of a person that has hostile intent towards the robotic system.

The first section will talk about the need for a good pedestrian detection system as a baseline for any anti-tamper algorithms. The lower quality the human detector, the lower

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **06 MAR 2005**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Pedestrian Detection for Anti-Tampering Vehicle Protection**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Michael Del Rose; Philip Frederick; Jack Reed**		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **USA TACOM 6501 E 11 Mile Road Warren, MI 48397-5000**		8. PERFORMING ORGANIZATION REPORT NUMBER **14748**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) **TACOM TARDEC** 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**8**	

quality the anti-tamper system will be. The following section will discuss the efforts that the Intelligence Systems Division is focusing on with respect to pedestrian detection. Section four will discuss anti-tamper systems available, and section five will talk about the current work that Intelligence Systems is focusing on with respect to anti-tamper. Finally, section six will conclude the paper followed by the references (section seven).

2. Pedestrian Detection Systems

Pedestrian detection is an important field of research. Autonomous and semi-autonomous vehicles need to identify people while traversing through the terrain in order to take appropriate actions to avoid them. Driver awareness systems, like those proposed by the Department of Transportation Intelligent Transportation Systems Division, need the ability to alert drivers of potential problems when driving through urban areas. Additionally, the Department of Defense needs pedestrian detection for path following and mule operations on robotic vehicles. In this paper, the focus is on pedestrian detection and its use in anti-tamper systems for robotic vehicles.

The research area of pedestrian detection is very large. There are many different approaches to this problem. Some use LADAR or laser scanners to retrieve a 3D map of the terrain and detect pedestrians [1,2,3,4], another uses ultrasonic sensors to determine the reflection of pedestrians [5]. Radar is also popular for detecting pedestrians similar to ultrasonic sensors; by measuring the reflection of possible targets and determining if they are pedestrians or not [6,7].

A natural choice for a sensor is vision because it is based on how people perceive pedestrians. Within the area of computer vision there are infrared vision, monocular vision, and stereo vision processes. Each vision system has its own advantages and disadvantages. Infrared systems [8,9,10,11] are not as sensitive to lighting conditions when compared to other visual sensors. However, they are more expensive and the image quality is not as good. Monocular vision systems [12,13,21] are cheap and require lower processing power, but they perform poorly at providing range data and are more sensitive to color and lighting. Stereo vision systems [14,15,16,17,18,19,20] have the advantage of being able to view potential objects from two points of view. They are also used to detect dispersion (or depth) of objects. The drawbacks of stereo vision systems are that they require more processing time and are sensitive to color and lighting conditions.

<u>Vision Systems</u>: Pedestrian detection is a difficult problem because of processing speed, robustness of vision sensor's algorithms, and a lack of maturity in computational intelligent systems to recognize everyday object. For the Department of Defense, specifically TARDEC, vision based detection is important for non-evasive pedestrian detection systems in path following, mule operations, surveillance, and driver awareness. The problem increases in difficulty when considering the movement of the sensors, uncontrolled outdoor environments, and variations in pedestrian's appearance and pose. There are many types of algorithms that try to address these problems.

Motion based systems are used to detect pedestrians from image sequences. They take into account the temporal information to detect periodic features of human movement [15,17,18]. This technique reduces the number of false positives from other methods, but requires a lead time of images, which causes a delay in the detection. Another drawback is that it is unable to detect people standing or making unusual movements (like jumping).

Template based systems [14,16,20] can be used on single frames so they do not require a lead time or movement of a pedestrian. The problem with most of these procedures is that they have difficulty in detecting variations in a pedestrian's appearance or pose.

One other common method is to detect body parts of person, then put them together in a logical form to determine the confidence of the target being a person or not [19,21]. This requires a lot of processing, but is good at detecting occluded people. Many false positives are due to matching potential body parts of things unrelated.

3. Intelligent System's Pedestrian Detection Program

The pedestrian detection program in the Intelligent Systems division looks at several different types of algorithms to detect people. The main focus is on visual and infrared sensor based pedestrian detection systems. Each algorithm is modeled for the environment it will be used in, from driver awareness systems to pedestrian following autonomous systems. Below is a description of the types of pedestrian detection projects currently being researched by the Human Detection and Intent Analysis Lab (HDIAL), under the Intelligent Systems Division.

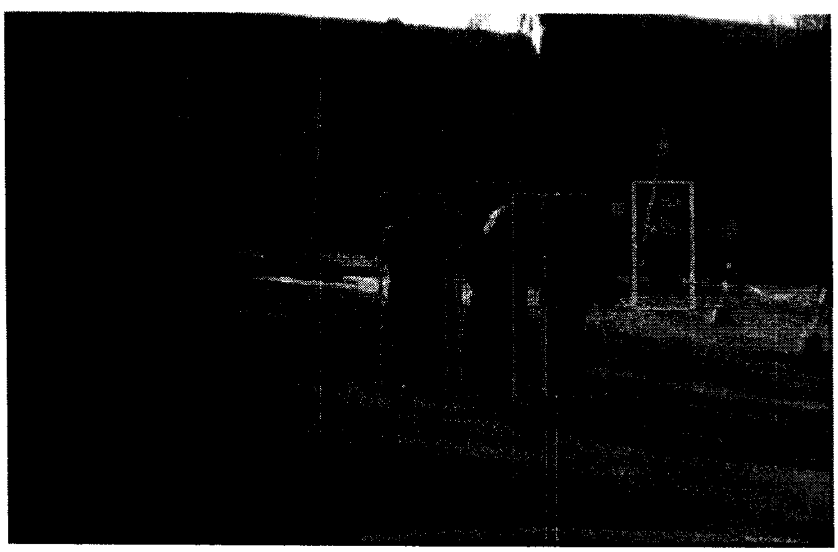

Figure 1. Gray-Scale Pedestrian Detection

Human Localization Using Gray Scale Stereo Imagery. This programs main purpose is two-fold. First it is used to detect humans in a single, stereo image and alert the driver of their location; second it provides an autonomous or semi-autonomous robotic system the location of people in the scene. It uses gray scale intensity mapping with depth information from the stereo cameras to single out possible people. Then it removes most all false positives by doing a head check of the candidates. Finally, it sends (or displays) the pedestrian location. See figure 1 for a visual view of this.

Human Localization Using Infrared Stereo Imagery. This program is used in conjunction with the Human Localization using gray scale imagery to improve the performance of pedestrian detection from single images. It first views the higher intensity areas and computes the distance of the areas in both left and right camera views. Any non-matched items are removed. Then it populates left over regions based on distance from the camera and combines them together based on proximity and typical human length/width ratios. The final processing checks for a head in the regions of interest and removes candidates without one. See figure 2 for a visual view of this processes.

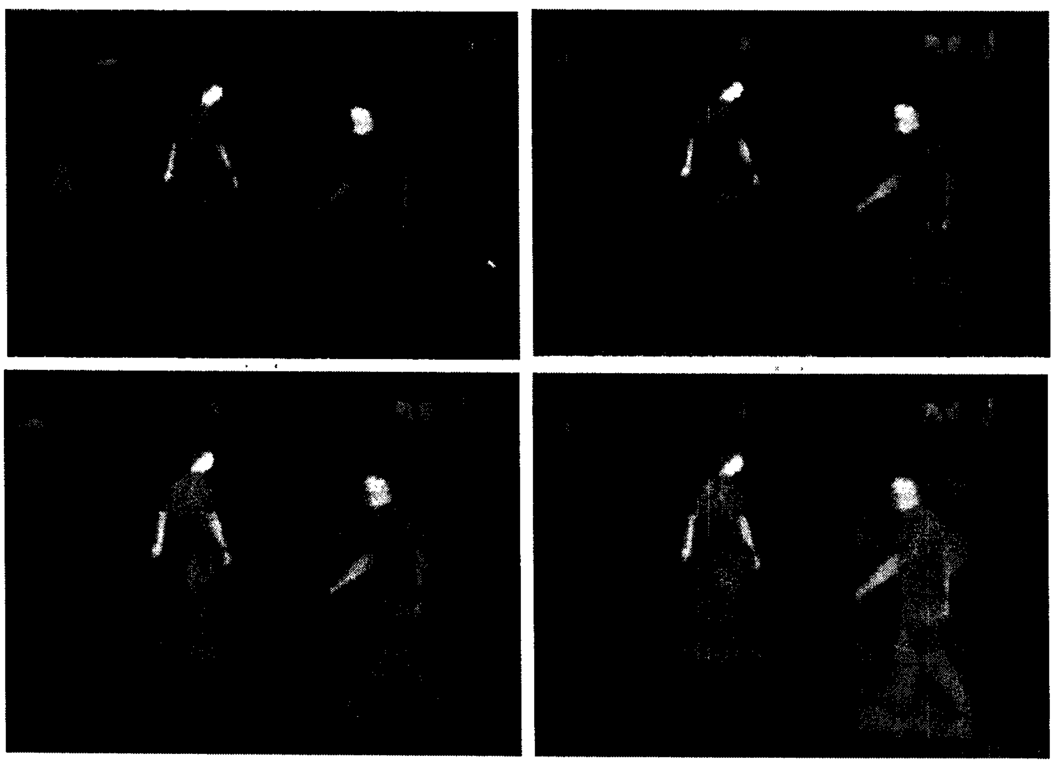

Figure 2. Infrared Pedestrian Detection Process.

The human localization project will combine both processing results of the infrared algorithms and the gray scale algorithms in a dynamic intelligent algorithm. The intent is

to choose the best pieces of information from both gray scale and infrared processing algorithms based on the vehicles current environmental conditions.

Color Stereo Pedestrian Detection. This project's main goal is to increase the current pedestrian detection systems by adding intelligent techniques to color processing. The color image is processed to cluster different shades of colors and distances from the camera. The image is then matched against templates for body parts (arms, legs, torsos, heads, etc.). Each possible body part is identified and a location from each other is used to determine if it is a feasible person (as well as which person each part belongs to). This will eliminate problems with occlusion of people in a scene.

Pedestrian Following. The main purpose of this project is to create an algorithm to track a particular person using color stereo cameras. It will be implemented on several different robotics platforms. The system will be operator initiated through the selection of a specific person to follow by clicking on the person through the human robot interface (from an image provided by one of the two cameras attached to the robot). Next, the pedestrian is segmented and blob clustering is performed based on color and disparity. This processed image is used as a template for the next frame. As the person starts to move, the region of movement from one frame to the next is calculated and the segmented image from the previous frame is used as a template to find the location of the pedestrian and matched. A distance from the cameras (0,0,0 world coordinates) to the pedestrian (x,y,z world coordinates) is computed and sent to the mobility process of the robot. The template matching is dynamic since each template changes from each frame. The computed location can be updated every second or every minute, based on the type of following preferred. It will also be designed to work on any GPS waypoint robotic vehicle. The waypoints will be computed by the calculations of the pedestrian locations.

Fused Infrared and Gray Scale Pedestrian Detection/Enhancement. This project is a joint effort between the HDIAL and the Perception Lab. The Perception Lab's effort is focused on human perception studies on fusion techniques between gray scale and infrared imagery. The HDIAL's focus is on using the same fusion techniques but applying machine intelligence to the problem. The goal of this project is to have the computer detect pedestrians with comparable results record by the human studies. An investigation into computer enhancement of the fused imagery will also be performed.

4. Anti-Tamper Systems

Anti-tamper systems are important to autonomous systems due to the need to characterize a threat from potential robotic or human interactions. The ideal anti-tamper system would be one that can see a person before being seen, move to a tactical position out of view, and take appropriate actions once being seen based on the person's perceived actions. It would be able to segment out the human, determine the human's intent, and either implement a warning system to deter the human, move out of the danger zone from the human, or radio an operator for further instructions.

Today's anti-tamper systems are mainly based on security devices where the sensors are in a static position, like building and parking lot security. For the army, specifically, military ground robotics, the need is to put these technologies on to moving platforms. A system that not only detects people, but also has the ability to determine the intent of the person requires an intelligence algorithm not available on most anti-tamper type systems. An anti-tamper system can be classified into two types of systems: a dumb system and a smart system.

A dumb anti-tamper systems main object is to identify moving objects. Many use radar, sonar, or even vision as the main sensor to identify changes in scenery, like movement of a person or animal. Once movement is identified from the system, either a warning signal to deter the moving object or an uplink to an operator to determine actions to take is initiated. These types of anti-tamper, or security, systems are in the "dumb anti-tamper" class because no intelligence is modeled to determine intent of the moving object.

Smart anti-tamper systems mainly consist of a sensor, or multiple sensors, and an intelligent algorithm that determines not only motion in the sensor field of view, but also reasoning on the changes. Because of the nature of determining intent in the scene, the system needs the details offered by visual systems. Some anti-tamper systems may include other sensors, but the main focus of the intent data is based on vision.

There are very few smart anti-tamper systems that are being used (or soon to be used) on security systems that determine the intent of a person [22,23] or a scene. The maturity of the smart systems have not reached a usable level, but the research into accomplishing this task is increasing. The main focus on this research is either through rule/logic based systems [24,25,26] or through probabilistic networks [27,28].

5. Current Anti-Tamper Program

The anti-tamper program in the intelligent systems division split the problem up into two parts: finding the humans (or pedestrian detection) and determining the intent of the humans. Pedestrian detection is a hard problem on its own. However, great strides are being made to isolate a person from the scenario. The HDIAL has designed and built many systems using their algorithms discussed above. Results are good. High detection rates with minimal false positives.

To determine intent, designs are being tested as well as software that is currently available. Research in this area is continuing and a system design should be completed by September 2005. Testing of the anti-tamper system should take place in June 2006.

6. Conclusion

Within the next decade robotic vehicles will be introduced into the battlefield in large numbers as a result of FCS. This will dictate a change in doctrine on how the Army fights. Robots and soldiers will be in the field together and need to coexist and function

in teams. It is imperative that these systems are free from aggressive actions by opposing forces. This is accomplished by including an anti-tamper systems module to all battlefield robotic systems.

TARDEC's Intelligent System's Human Detection and Intent Analysis Lab is focused on providing a quality anti-tamper system to detect aggressive actions from humans and supply information to operators when hostile actions have been identified. This effort will feed Intelligence System's Army Technology Objectives (ATOs) such as Armed Robotic Vehicle (ARV) Robotic Technologies (ART) and Human Robot Interface (HRI). These ATOs provide technologies that transition to FCS platforms.

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